Civil Air Patrol

ADVANCED MODEL ROCKETRY

Columbia Stage Four

Challenger Stage Five

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Challenger Stage Five

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NATIONAL EDUCATIONAL STANDARDS
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National Standards

SCIENCE STANDARDS: National Research Council (NRC)

Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Standard B: Physical Science
- Properties and changes of properties in matter
- Chemical reactions
- Motions and forces
- Transfer of energy

Standard E: Science and Technology
- Abilities of technological design
- Understandings about science and technology

Standard F: Science in Personal and Social Perspectives
- Risks and benefits
- Natural and human-induced hazards
- Science and technology in society

Standard G: History and Nature of Science
- Science as a human endeavor
- Historical perspectives
- History of science

Unifying Concepts and Processes
- Constancy, change, and measurement
- Evidence, models, and explanation
- Form and function

MATHEMATICS STANDARDS: National Council of Teachers of Mathematics (NCTM)

4. Measurement Standard
- Understand measurable attributes of objects and the units, systems, and processes of measurment.
- Apply appropriate techniques, tools, and formulas to determine measurements.

5. Data Analysis and Probability Standard
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.

6. Problem Solving Standard
- Solve problems that arise in mathematics and other contexts.

8. Communication Standard
- Use the language of mathematics to express mathematical ideas precisely.

9. Connections Standard
- Recognize and apply mathematics in contexts outside of mathematics.

TECHNOLOGY STANDARDS: International Technology Education Association (ITEA)

Standard 8: Understanding of the attributes of design.
Standard 10: Understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
Standard 11: Ability to apply the design process.

SOCIAL STUDIES STANDARDS: National Council for the Social Studies (NCSS)

2. Time, Continuity, and Change
6. Power, Authority, and Governance
8. Science, Technology, and Society


COLUMBIA
Stage IV
USA

COLUMBIA
Requirements

COLUMBIA (Stage 4) Requirements:

To remain consistent with the three earlier stages of the CAP Model Rocketry Program (Redstone — which launched America's first one-man spacecraft, Titan — which launched the first two-man craft, and Saturn — which launched the first three-man craft), it follows then to name stage four, COLUMBIA, as it was Space Shuttle Columbia that launched the first four-person crew on STS-5, November 11, 1982. Hence, Stage 5 will be called CHALLENGER, as it was Space Shuttle Challenger that launched the first five-person crew on STS-7, June 18, 1983. It also serves to honor those lost on both of these shuttles during the STS 51-L and STS-107 missions.

1. The Written Phase

Before going to the hands-on phase, the cadet must successfully pass the review on composite propellants, added forces on a rocket using composite propellant motors, thrust curves, and advanced construction techniques. The questions are available on CAP's Learning Management System (LMS). Log in one Services, click on LMS then go to aerospace education's section or the unit Aerospace Education Officer (AEO) can administer the questions to you.

2. The Official Witness Log (OWL) for review questions

The cadet must have the unit AEO sign the OWL after a successful score is achieved by the cadet.

3. The Hands-On Phase

The cadet must build a mid-power model rocket kit from an established mid/high-power rocketry manufacturer, such as LOC-Precision, Public Missiles Ltd., or Aerotech Consumer Aerospace.

4. The Official Witness Log (OWL) and Rocket Flight

The cadet must have an AEO or other Qualified Senior Member (QSM) witness the successful launch and recovery of the completed rocket on either an E, F, or G-class single use ammonium perchlorate composite propellant (APCP) motor.

5. The Squadron Commander Sign-Off

After completion of all the above requirements, the cadet is entitled to the Columbia certificate. The Squadron Commander must review the completed Official Witness Logs and sign this certificate so the cadet may advance to the Challenger stage. It is recommended that the certificate be presented at a squadron awards ceremony.

"MID-POWER" ROCKETRY

In stages two and three of the CAP Model Rocketry Program, you successfully flew and recovered what is typically regarded as "traditional" model rockets. These rockets usually weigh less than a pound and fly to limited altitudes, which allow them to be flown in many open spaces without special permission or licenses. Traditional model rockets are usually simple to build, relatively inexpensive, and are generally quite safe.

A first step beyond traditional model rocketry is what may be termed **Mid-Power Rocketry**. Rockets in this category typically use composite propellant motors in the E through G sizes, although black powder E motors are also available. Mid-power model rockets generally weigh less than two pounds, but can fly higher than traditional model rockets.

Model rockets containing no more than 4.4 ounces (125 grams) of propellant and weighing no more than 3.3 pounds (1500 grams) may be flown without special permission or licenses. Mid-power model rockets are not necessarily more difficult to build than traditional model rockets, but may require knowledge of some advanced construction techniques in order to account for the added stresses that composite propellants will provide. Composite propellant mid-power rocket motors are more expensive than the smaller black powder rocket motors but usually cost less per unit of power.

High power rocketry (discussed in Stage V) is so termed based on the total impulse (power) developed by the motors.

COMPOSITE PROPELLANT

Composite Propellant — in general terms — means that the propellant is a mixture of ingredients (fuel and oxidizer substances) that when mixed together, solidify by means of a chemical reaction. The chemical reaction is similar to mixing up epoxy; when Part A and Part B are mixed, the chemical reaction causes the mixture to harden.

By contrast, **Black Powder** propellant is a powdery substance that is "pressed" into a hard slug. Black powder is a pressed mixture of potassium nitrate, sulfur and charcoal. This propellant has been used for hundreds of years but has relatively low performance. In contrast, composite propellant is usually composed of a mixture of ammonium perchlorate, synthetic rubber and a metal fuel like powdered aluminum. Because of its superior performance, it is commonly used in all sorts of military rockets and the Space Shuttle solid rocket boosters (SRBs).

Some of the fundamental differences between "Black Powder" motors and composite propellant are:
- Composite propellant has up to 3 times the power of black powder by weight.
- Composite propellant model rocket motors are usually **core burning** and are ignited at the head end of the propellant grain instead of the nozzle end.
- A reinforced plastic or metal case is used in a composite rocket motor instead of a wound paper case.
- The composite model rocket motor nozzle is reinforced plastic instead of pressed clay.
- The bulkhead end of the composite rocket motor is cast epoxy or molded plastic.
- Composite model rocket motors are much louder and more spectacular than black powder model rocket motors.

To help illustrate this point, let's compare two motors of a similar size: one a black powder motor, the other a composite propellant motor.

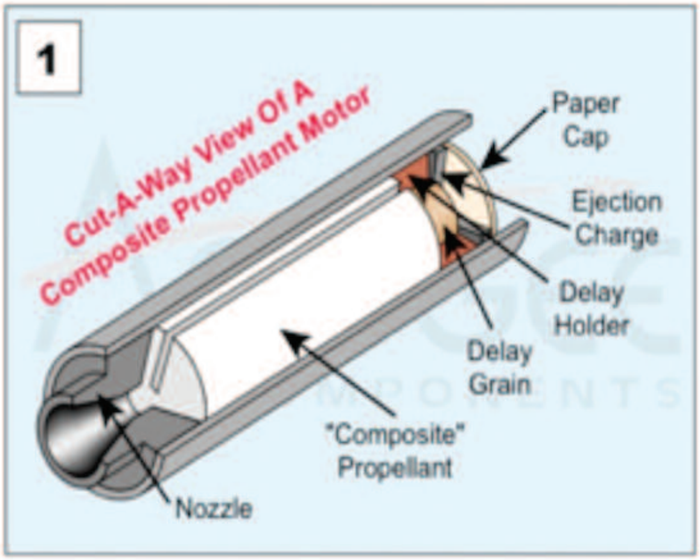
First, the black powder motor:

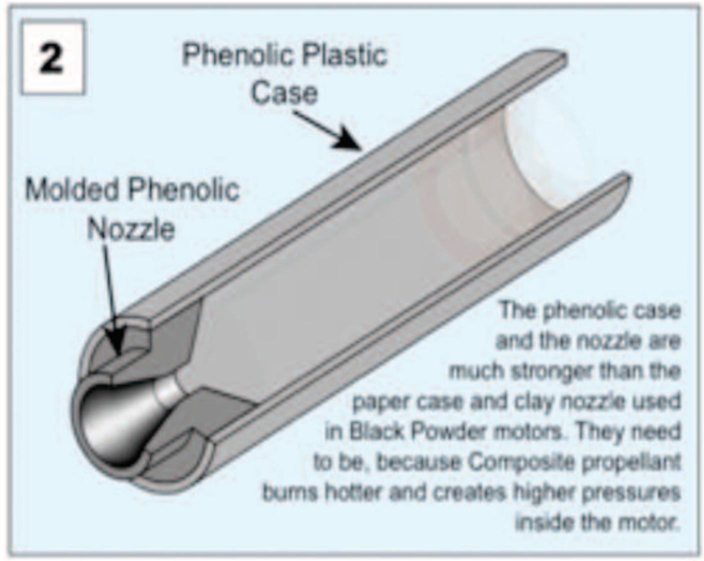
D12 – 21 grams of propellant producing 16.8 N-sec of power

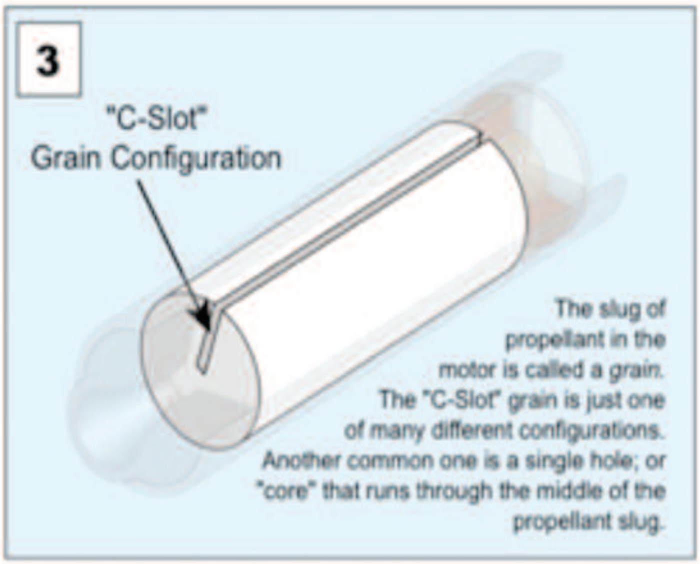
Next, the composite propellant motor:

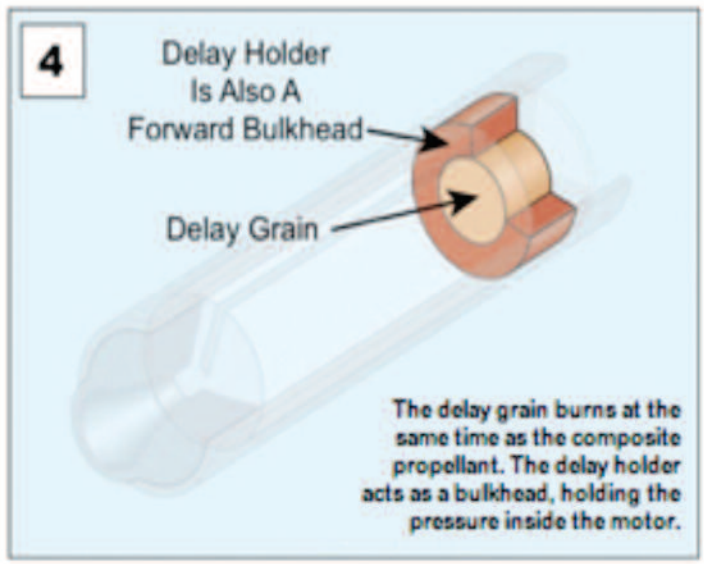
F24 – 19 grams of propellant producing 47.3 N-sec of power

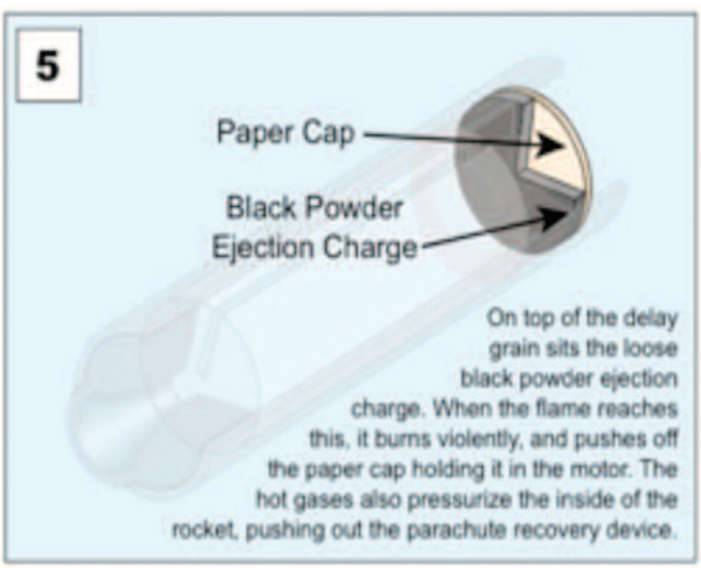
INSIDE THE COMPOSITE PROPELLANT MOTOR

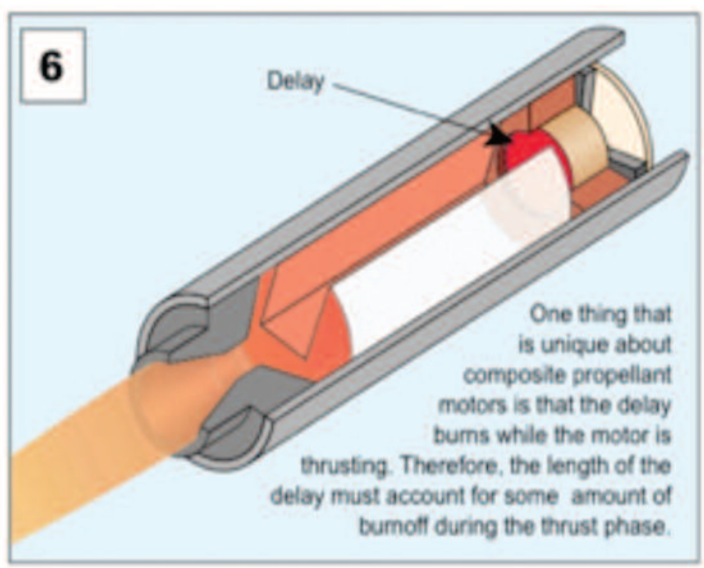












THRUST CURVES – UNDERSTANDING THE STRESSES

With the enhanced power of composite propellant motors, come significantly higher stresses on your model rocket. These are stresses that need to be understood and accounted for in the rocket's construction.

To understand the added stresses that composite propellant can apply to a model rocket, a fundamental understanding of **Thrust Curves** and what they depict is required.

A thrust curve is a two dimensional graph that documents the amount of power, or thrust, a rocket motor produces, measured in **Newtons** (N) over the time span of the motor's burn, measured in seconds (sec).

Of the four fundamental forces acting upon an aircraft in flight, thrust, gravity, and drag are the three that will most affect how high your model rocket will fly. During powered flight, the motor provides thrust and the rocket accelerates upward. Because of this, the velocity (affected by the force of gravity) and drag increase dramatically.

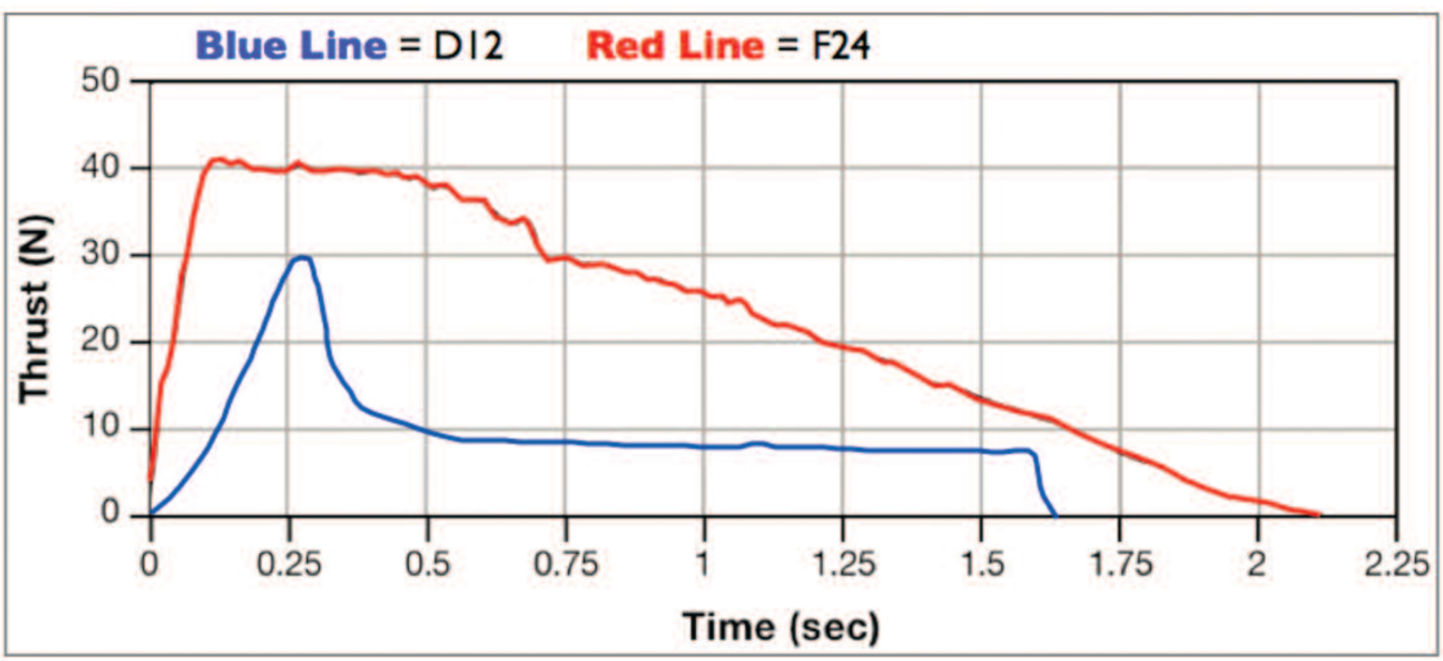
Near the end of powered fight, model rockets will reach what is commonly referred to as **Max-Q**. Max-Q is the point in flight when the rocket encounters the maximum dynamic pressure, or the moment at which aerodynamic stresses on a rocket in atmospheric flight are maximized. For model rockets, which stay in the lower atmosphere, Max-Q occurs at maximum velocity, which is usually where a rocket that is not built to withstand those forces, will begin to break apart, or shred.

Understanding a rocket motor's thrust curve will help you know how your rocket will perform against the forces of gravity and drag, which can provide not only valuable information on how high your model rocket could fly, but also how it should be constructed in order to keep it in one piece while doing so.

To get a visual understanding of the power differences between Black Powder and Composite Propellant motors, let's take the two motors shown on the previous page - the *Estes D12* and the *Aerotech F24*, and compare their respective thrust curves, shown in the graph below.

If you remember, the *Estes D12* has 21 grams of propellant weight, boasting 16.8 Newton-seconds of Total Impulse – the amount of power packed into it. The *Aerotech F24* on the other hand weighs a little less, 19 grams, yet has 47.3 Newton-seconds of total impulse. And where the D12 stays at its maximum thrust peak of 30 Newtons for just a moment, the F24 stays at its maximum thrust peak of 40 Newtons for much longer.

To address the significant increase in the aerodynamic stresses placed on the rocket, we need to learn how to build a stronger rocket in the next section.

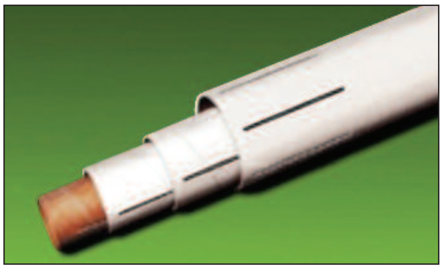


INCREASED POWER CALLS FOR TOUGHER MATERIALS

As the motors get more powerful, the materials used to build mid/high-power rockets need to be stronger and more resistant to the forces that will be placed upon them. Where as paper, light cardboard, and balsa wood work well for traditional rockets, mid/high-power rocketry requires different materials if the rocket is to perform to expectations. Some of these materials are listed below.

Kraft Cardboard Tubing

This is strong yet lightweight fiber tubing designed for close tolerances, working ease, and durability. This material is usually brown with a tightly wound Glassine overwrap for quick paint finish and is used primarily for airframes, motor mount tubes, and couplers.



Phenolic Cardboard Tubing

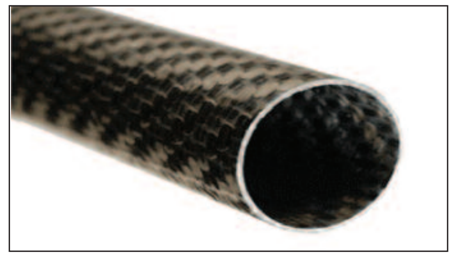
Phenolic tubing is a resin impregnated, spiral wrapped, and heat cured tube. It is much stronger than cardboard tubing, with almost 5 times the compression strength.

Fiberglass

Epoxy based filament wound tubing and fiberglass sheets make an incredibly sturdy material that is the strongest money can buy, next to metal. Fiberglass can be used for a number of purposes, from being wrapped around and hardened to reinforce a cardboard airframe, to being cut into fins and centering rings.

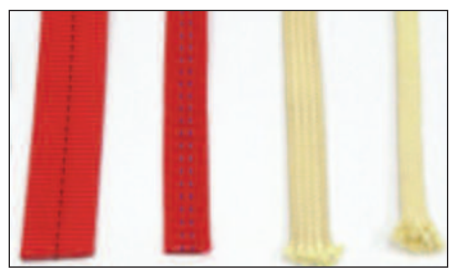
Carbon Composite Material

Carbon Fiber is a material consisting of extremely thin fibers composed mostly of carbon atoms. Carbon fiber can be combined with a plastic resin and wound or molded to form composite materials such as carbon fiber reinforced plastic (also called carbon fiber) providing a very high strength-to-weight ratio material—in some cases, even stronger than metal.



Tubular Nylon/Kevlar

There are many types of webbing and small rope that can be used as your rocket's shock-cord. Among the most popular is **tubular nylon** (below, left). It is more than twice as strong as the same width of non-tubular nylon webbing, yet it has almost the same thickness. **Tubular Kevlar** (below, right) has less stretch than nylon, but has a much higher tensile strength and is fire retardant, making it an ideal shock-cord or recovery material.



Epoxy Adhesive

Epoxy is a durable glue type that provides a high level of bonding properties, far superior to most ordinary paste-style glues. Generally sold in a two-component package that requires mixing just before use, epoxy is used to securely bind a number of different types of metals, plastics, and woods, making it an excellent adhesive for use in mid/high-power rocketry.

ADVANCED CONSTRUCTION TECHNIQUES

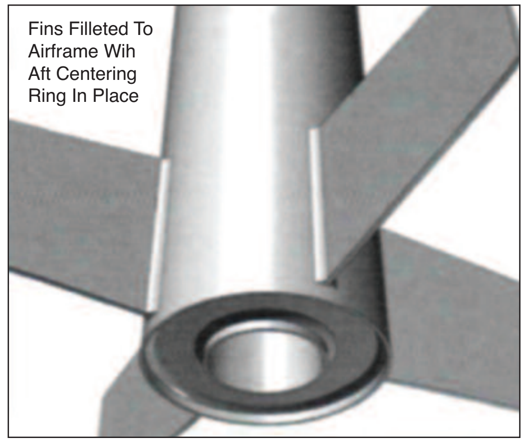
Some advanced construction techniques can be employed to bring a greater degree of strength and resiliency to your model rocket. Doing so increases the chance of flying your rocket multiple times without worrying that the motor you choose will rip the rocket apart.

There are a number of techniques that mid/high-power rocketeers will utilize during the construction of a rocket. The following methods are some of the most basic known, but can be utilized from a very small rocket; to the largest ones you'll ever try to create.

Fin Fillets

One of the most vulnerable parts of your rocket are the fins. Increasing the surface area of your fin joint will keep fins attached through those high-performance flights, especially if your fins are attached directly to the airframe (surface mounted). The simplest reinforcement is a **fin fillet**, which forms a smooth joint between the airframe and fin surfaces.

Below is a good method of creating effective fillets every time, which will require very little sanding. For this method, use 15-minute epoxy. Note that you can only do two fillets at a time.



1. Place the airframe in a jig or holder of some sort that will position it horizontally without the fins touching. Hang the fins off the tabletop if necessary.

2. Turn the airframe so that 2 fins are pointed up and the fin tips are level. They should look like the letter "V". The two fillets inside of the "V" are the ones that will be filleted.

3. Put masking tape on each end of the fillet where epoxy could run off and down the side of the tube. Make a dam with it. Do this on all four corners of the fillets you are working on.

4. Mix enough 15 minute epoxy to put about 1/4" thickness over both fillets and carefully pour it onto the fin/airframe joint surface and allow it to level out to both ends. Lift the airframe and tilt it forward and backward to accommodate the spreading of the epoxy.

5. When the epoxy has settled evenly to both ends, rotate the airframe side to side to run it up on the fin and the airframe a good 1/4" to 3/8" above the joint. Rotate the other direction to complete the flowing out of the epoxy and then return it to the centered leveled position where both fin tips are level.

6. By this time, the epoxy should be beginning to set. Take your finger, dip it into a small container of rubbing alcohol and run it up and down the epoxy fillet to smooth it out. The alcohol will allow you to smooth the joint perfectly. Another method is to "shape" the fillet using a plastic spoon. The tip forms the fillet and the excess epoxy curls up into the bowl of the spoon instead of overflowing off the sides.

7. Allow the epoxy to dry sufficiently so as not to sag when rotated around for the other fillets.

8. Once all fillets are done, let them dry overnight and remove the masking tape dams. Sand smooth transitions into the front and rear of the fillets using a round file and then sandpaper.

Through-the-Wall (TTW) Fin Attachment

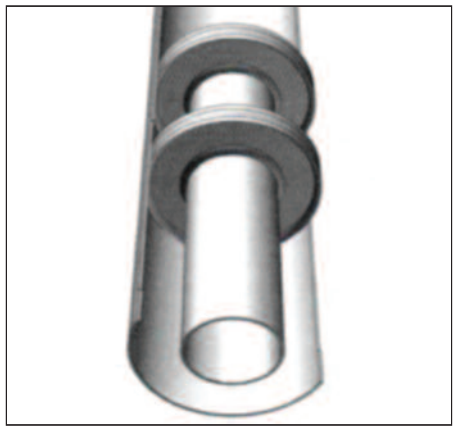
Through-the-Wall fins have tabs that go through the airframe and bond directly to the motor tube. This requires fin slots to be cut through the airframe. TTW fins achieve greater strength by providing multiple locations (that's surface area) to bond the fins to the airframe and motor tube. Fillets can be placed on the inside and outside of the airframe and on the motor tube, especially if the aft centering ring is removed to permit access to the interior of the rocket.

To get this access, slide in the motor mount and centering rings, but glue only the forward centering ring to the motor tube—do not put any glue on the aft centering ring and make sure a small portion of the ring protrudes from the end of the body tube. A third centering ring, between the forward and aft rings can provide a contact point for the front edge of the fin being mounted. Note that some designs will use only two rings, while others will use three.

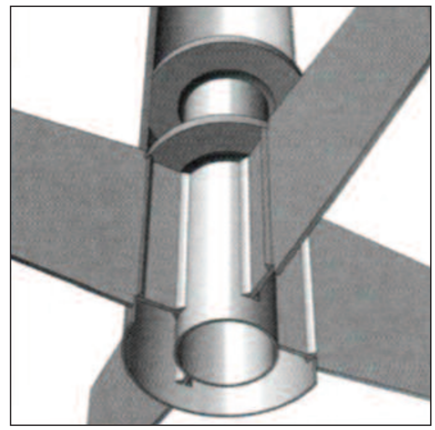
Once the forward ring/s are glued in place and have dried, carefully remove the aft, using a hobby knife.

Once the aft ring is removed, you will have access to the TTW fins, and can now put glue fillets or reinforce-ments on every fin/airframe joint. This makes an incredibly strong fin joint. Once all the glue is set, the aft centering ring can be glued into place. The steps provided here represent an overview of the process—kit manufacturers will include more detailed instructions.

Motor Mount Tube With Front and Middle Centering Rings



Cutaway Airframe With Motor Mount Assembly

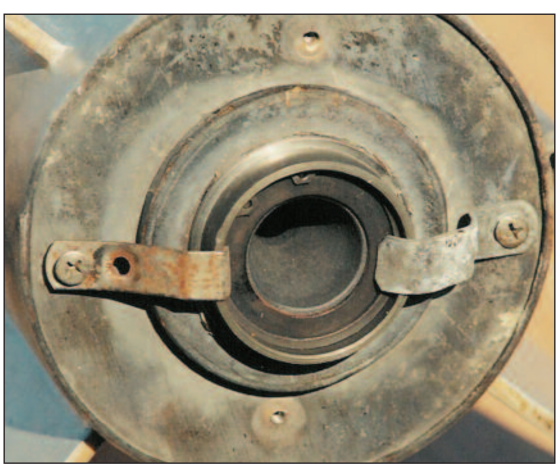


Cutaway Airframe With TTW Fins Glued To Motor Mount Tube

Motor Retention

In mid/high-power rocketry, the rocket motor must remain in the airframe between the moment of ignition and the conclusion of recovery. This is for at least two reasons. First, the reloadable motor casings that are often used (we'll learn about these in Stage 5) are expensive. If the casing is dislodged during flight, the motor will fall out and may never be seen again. Second, motor retention ensures the safe return of the ENTIRE rocket.

If a mid/high-power rocket is using motor-based ejection charges (black powder charges located in the forward closure of the motor) insufficient motor retention will result in the motor being ejected out the aft end of the rocket when the ejection charge is fired. Not only will the motor be lost, but also the nose cone may not separate due to insufficient forward pressure in the airframe. The rocket's shock cord or recovery harness will not deploy, and the rocket will return to the ground as what is commonly called a "lawn dart" because it strikes the ground nose first high speed – an extremely unsafe situation.

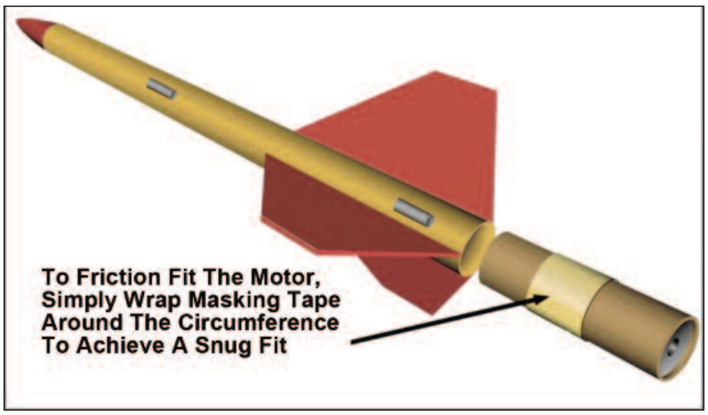


Fortunately, quality motor-retention systems are simple to create and easy to install – even in rockets that have already been built. Motor retention systems may be purchased in prepackaged kits from rocketry vendors such as Aeropac, Public Missiles, or Giant Leap Rocketry. But they can also be scratch-built with components available at most hardware stores. Once you've seen a few homebrew setups, and asked some questions at a mid/high-power rocket launch, you will be ready to make your own system.

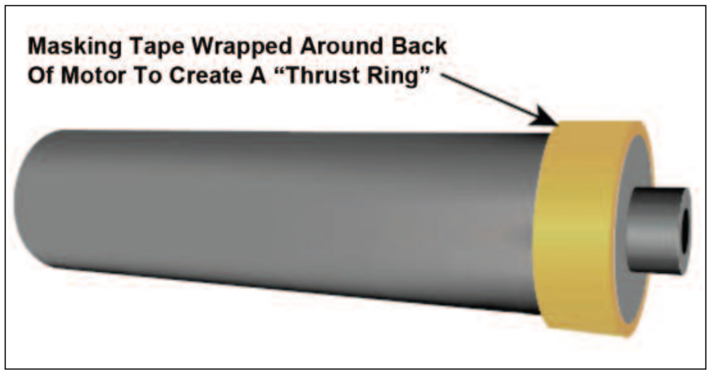
The kits you flew in Stage 2 and Stage 3 of the CAP Model Rocketry Program used motor hooks to retain the motor inside the rocket. But as you enter the realm of mid/high-power rocketry, you'll find that not only do most rocket kits not use motor hooks, they don't come with a motor retention system at all. Some kits don't even mention them.

Motor hooks in mid/high-power rocketry are no longer practical because motor hooks are designed for usually just one length of rocket motor. Bigger motors are often the same diameter but have different lengths, as shown in the photo below. And the thrust ring (sometimes referred to as an "engine block") is no longer inside the rocket, but on the motor itself, if at all.

In this stage of the Advanced Rocketry Program, we'll be using a single-use rocket motor in the E, F, or G impulse class. And motor retention for these single-use motors can be achieved by the simple use of masking tape for the Friction Fit Method.



The Friction Fit Method – This method involves simply wrapping masking tape about the mid-section of a single-use motor, enough that it creates a more than snug **friction fit** into the rocket's motor tube. The fit should be tight enough to make removal difficult, but not impossible.

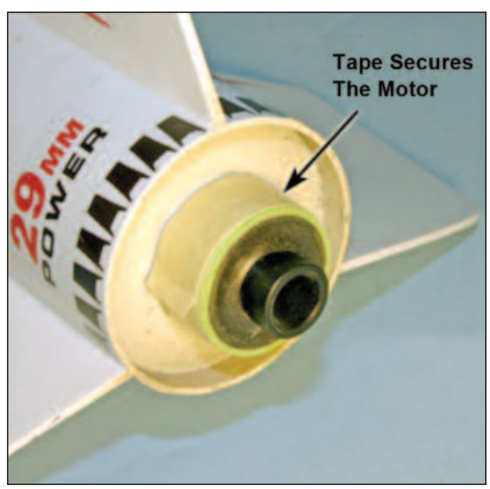


The Thrust Ring Method – To begin, wrap many layers of tape around the aft end of your motor to build up a thrust ring.

Make sure the motor mount tube sticks out the back of the rocket by about 7/10 inch (18mm). <u>Always build your rocket this way, even if it means you are deviating from the instructions.</u>

When you're ready to install the motor, just slide it into the motor mount tube as shown in the picture below. The thrust ring on the back will prevent the motor from going in too far.

Once the motor is inserted, take some masking tape, and simply wrap two or three layers of it over the motor and the motor mount tube.

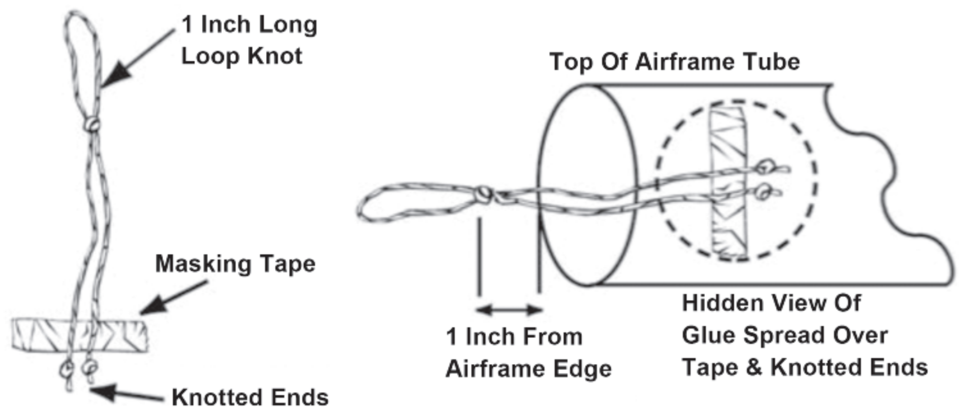


Shock-Cord Attachment Points

Nowhere does focusing on surface area pay more dividends than in recovery-system construction. An adequate system has to handle about fifty times the rocket's weight as it slows the rocket to a safe descent rate. The ideal situation is to spread this load out over a large area. Attaching the recovery system in two or three places or bonding the recovery strap down the side of the motor tube or along the edge of two or three through-the-wall fins are some ways to spread that recovery load across the rocket. In the model rocket kits you used for Stage 2 and Stage 3, you were advised to glue an end of the shock cord in a paper tab and then attach the tab to the airframe sidewall. This technique works well for small, light rockets but generally not on the larger, heavier ones found in mid/high-power rocketry.

Below, we'll explore a few of the shock-cord attachment point techniques that are employed in one form or another in almost all mid-power rocket kits.

The Looped-String Method – This method is easy to make and install, yet is very strong. This mounting system is most prevalent in kits manufactured by the rocket company, LOC-Precision.



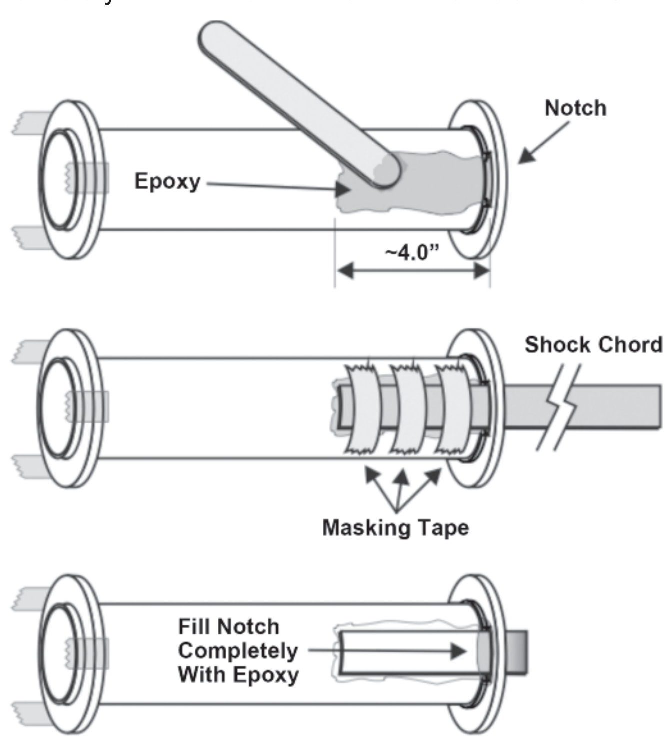
1. Take the length of nylon braided cord and at its center make a 1" long loop knot and pull it tight. Make a knot a 1/4" away from the end of EACH of the two loose ends.

2. Cut a piece of masking tape 1/4" wide by 1 1/4" long. This is centered cross-wise just ahead of the two knots.

3. Carefully place the two knotted loose ends of the Shock Cord Mount with tape attached, inside the top of the airframe tube so that the 1" long loop knot is protruding out about 1" from the airframe tube's edge. Ensure the mount is installed far enough down the airframe wall so as not to interfere with subsequent nose cone installation. Using a small piece of wooden dowel, press the masking tape down firmly around the inside of the airframe tubing. The masking tape will keep the Shock Cord Mount in place while gluing.

4. Place a generous bead of epoxy over the knotted ends and length of masking tape. Spread the glue around until they are completely covered and place the airframe in a horizontal position to dry. REPEAT STEP 4 UNTIL A SMOOTH GLUE LAYER IS ACHIEVED OVER THE MASKING TAPE AND KNOTTED ENDS.

The Motor Mount Attachment Method – This method creates a very strong and effective attachment point for your shock cord by gluing it flat to the surface area of your rocket's motor mount tube, which is itself heavily fortified in its attachment to the centering rings.



A benefit of this method is that it affords, especially on smaller diameter rockets, all the space in the payload area in which to stow the parachute and rest of the shock cord. There's nothing on the inside airframe wall taking space up or causing a snagging hazard.

1. If the kit manufacturer hasn't done this already, make a small notch on the inside of the forward centering ring, about 1" long, and ¼" deep.

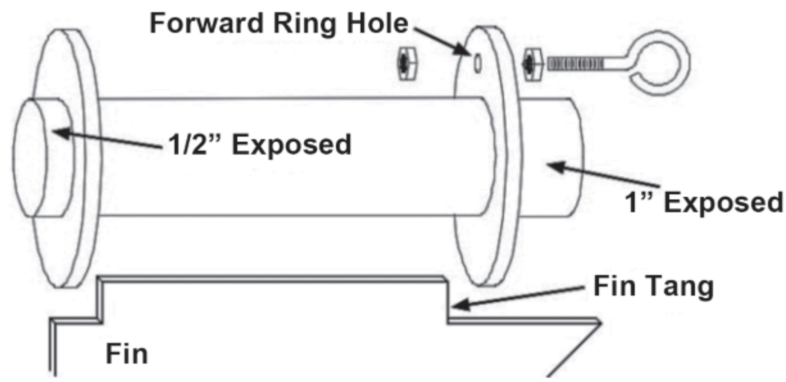
2. Spread a layer of epoxy about 1" wide and 4" long on the motor tube just below the notch in the upper centering ring.

3. Slip one end of the shock through the notch in the forward centering ring. Pull through about 4” of this strap through the notch and press it firmly into the epoxy on the side of the motor tube.

4. Hold the strap in place against the tube with masking tape until the epoxy cures. Remove the masking tape.

5. ***Fill the entire centering ring notch with epoxy.***

The Eye-Bolt Method – This method is perhaps one of the easiest, yet most effective ways of attaching your shock cord to your rocket. The **Eye-Bolt** Method provides a great deal of strength and resiliency to your rocket’s recovery system and is the principle concept for the preferred method of shock cord mounting in mid/high-power rocketry.



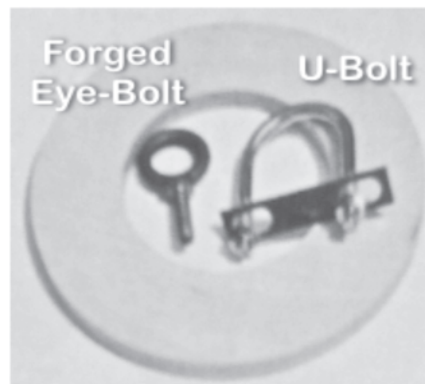
1. Drill a hole in the facing of what will be your forward centering ring. Make sure the hole will allow you to screw the threaded part of the eye-bolt in.

2. Mount the eye-bolt in the forward ring hole using the two nuts as shown in the diagram. Washers, although not shown in the diagram, should be used on both sides of the centering ring.

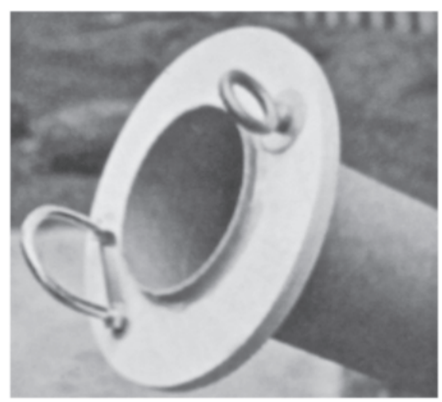
3. Apply some epoxy to the nuts to ensure they will not come loose later.

4. Attach one end of the shock-cord to the eye-bolt using an overhand knot.

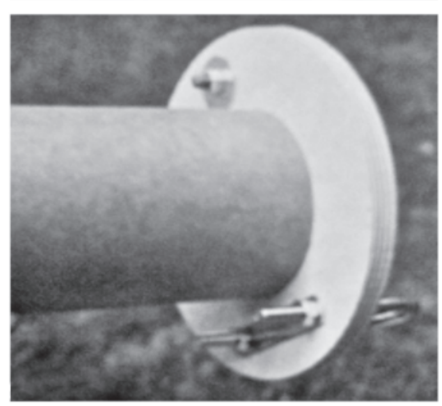
IMPORTANT – you must do this BEFORE gluing your motor assembly into the rocket. Also, make sure the eye-bolt and nut are aligned properly so the motor assembly can slide into the motor tube.



The High-Power Rocket Shock Cord Attachment –
An open eye-bolt, like the one shown in diagram, will work fine in traditional model rockets and mid-power rockets. But as the rockets get bigger, so do the stresses placed on your recovery system. A large rocket using open eye-bolts for shock cord attachment can run a very real risk of bending open should that rocket’s recovery system endure extreme stresses during a recovery sequence that is off on its timing. An open eye-bolt can mean an unattached shock cord, which can mean an unattached parachute, which can mean the end of the rocket.



To help avoid these circumstances, high-power rocketeers will use **U-Bolts** or **forged eye-bolts** (eye-bolts that are closed) as their shock cord attachment points. As they can’t bend like open eye-bolts, U-Bolts and Forged Eye-Bolts make a great alternative when looking to minimize the chances of a recovery system failure. Both types of bolts are built into the motor mount assembly pictured to the right.

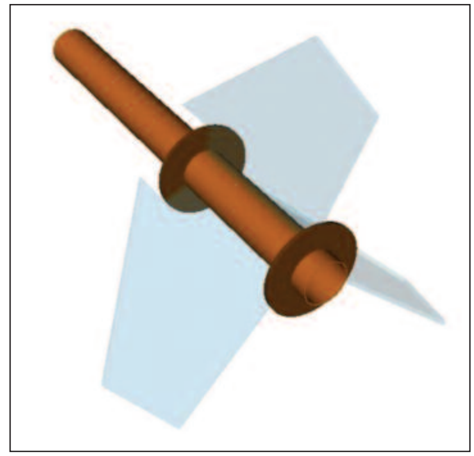


Internal Reinforcement: "Push Me, Pull You"

Being able to effectively distribute the loads that a mid/high-power rocket will endure during flight is one way to ensure that your rocket performs as designed, and will come back, ready for more.

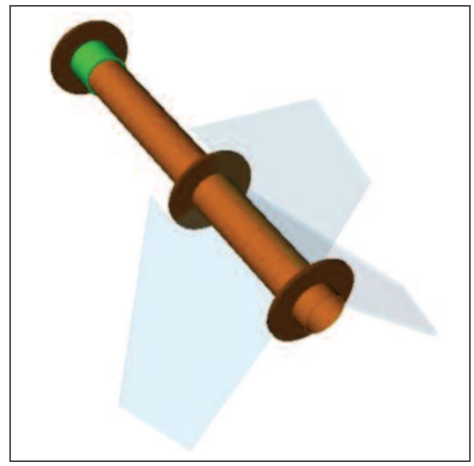
Good load distribution comes down to how much surface area you can utilize. A simple, yet extremely effective, technique to deal with load distribution is the **Push Me, Pull You** technique.

Pictured to right is an uncompleted motor mount assembly, without its forward centering ring. This motor mount assembly will have three centering rings, but you can do this technique with two. The faded fins are shown for orientation.



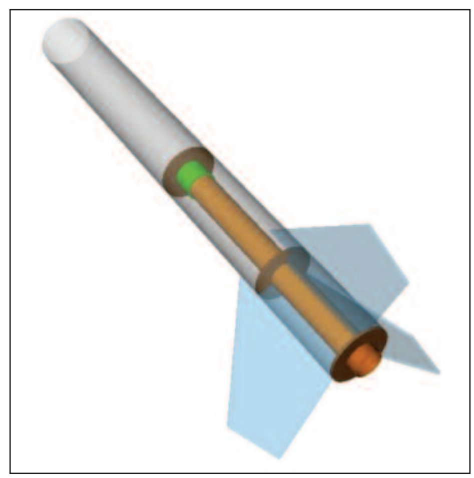
1. Take a 2" segment of spare motor mount tubing, in the same diameter as the one being used in the rocket. Cut a slit from top to bottom, the full length of the piece.

2. **BEFORE** putting your forward centering ring in place, slide the 2" tubing (in green) over the top of the rocket's motor mount tube. Slide the 2" piece down about an inch from the top. Slide your forward centering ring down over the top of the motor mount tube until it rests on top of the 2" piece. Glue both in place with a generous amount of epoxy.



3. Glue your motor mount assembly inside the airframe.

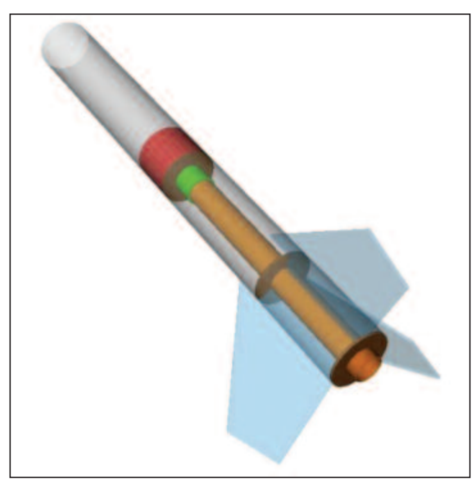
4. Take a 2 - 4"piece of COUPLER tube (in red) that is compatible with the diameter of the airframe being used, and slide it down into the top of the rocket until it makes contact with the forward centering ring. (Coupler tubes are tubes used to conjoin segments of a rocket with a long airframe). Glue the coupler tube piece firmly into place.



Building these two simple and lightweight pieces into the rocket provides two significant benefits to the rocket while adding very little additional weight.

First, the motor mount tube ring (in green) is able to transfer more of the loads imparted on the motor tube during powered flight, into the forward centering ring and coupler tube piece right above it. In effect, absorbing much of the rocket motor's force during its thrust phase. This is the "push".

Second, if the shock cord attachment point is either located on the forward centering ring (Eye or U-bolt) or on the motor mount (Motor Mount Attachment Method), then the coupler tube piece (in red) serves to distribute the loads on the centering ring or motor mount tube during the sometimes violent forces encountered during recovery system activation and deployment. This is the "pull".



Stage IV of the CAP rocketry program introduces the cadet to the advanced construction techniques that are required for mid and (more importantly) high power rocketry (HPR), while Stage V is designed to introduce the cadet to reloadable HPR motors as well as important information regarding HPR safety. The culmination of Stage V results in the award of a Junior High Power Rocketry Certification through the National Association of Rocketry. The minimum age requirement for Jr. HPR certification is 14, and can be obtained through age 17. Once an individual turns 18, he or she would follow the normal certification procedures for adults; however, individuals who certify at the Jr. level do not have to recertify when they turn 18.

Considerations for Stage IV Rocket Kit Selections

CAP, in recognition of the higher costs associated with high power rocketry, will make a provision to use the same rocket built in Stage IV to complete the NAR Jr. HPR certification at reduced cost. Through this provision, the cost of purchasing and building a Stage V rocket is eliminated. All that will be necessary is to pass the written examination and fly the Stage IV rocket successfully on an H impulse motor.

Not all Stage IV rockets are designed to fly on high power motors (H and above) so it is important to select a rocket that <u>can accommodate an H motor</u> if the high power certification option is to be exercised. The following list will give an example of one or two kits from a selection of established manufacturers that are suitable for Stage IV as well as Stage V (meaning that it can also accommodate an H motor). The manufacturers and kits available are too numerous to list them all.

Manufacturer	Kit
Aerotech	Sumo
LOC/Precision	Graduator
LOC/Precision	Loc IV
PML	Io (eye-oh)
PML	Callisto

<u>With proper kit selection, the same rocket used in Stage IV can also be used in Stage V, which will result in considerable cost savings.</u>

NATIONAL ROCKETRY ORGANIZATIONS

National Association of Rocketry (NAR)
Locate Rocket Sections
(www.nar.org/NARseclist.php)

Tripoli Rocketry Association (TRA)
Locate Rocket Prefectures
(www.tripoli.org/prefecture/prefusfl.shtml)

ESTABLISHED ROCKETRY VENDORS

Aerotech Consumer Aerospace
www.aerotech-rocketry.com

Public Missiles Ltd.
www.publicmissiles.com

Loc Precision Rocketry
www.rocketsbymelissa.com

Apogee Components
www.apogeerockets.com

Cesaroni Technology Incorporated
www.pro38.com

ALSO CHECK OUT THESE GREAT INFORMATIONAL RESOURCES:

FLYROCKETS.COM
A great source for information and instruction on all phases of model rocketry
www.Flyrockets.com

ROCKETRYPLANET.COM
The best site on the web for keeping up with what's happening in the world of model rocketry
www.rocketryplanet.com

ESSENCE'S MODEL ROCKETRY REVIEWS & RESOURCES
The best source on the web for reviews, insights, and ideas on building many of the kits offered by most rocketry manufactures.
www.rocketreviews.com

ROCKETS MAGAZINE
High-power rocketry's premier hobby magazine. The official magazine of the Tripoli Rocketry Association.
www.libertylaunchsystems.com

THRUSTCURVE.ORG
The best source for performance and thrust curve data for every motor currently certified by the National Association of Rocketry, Tripoli Rocketry Association, and the Canadian Rocketry Association.
www.thrustcurve.org

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Books

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- Newton, Mark. “Building a Rocket.” NAR Member Guidebook Volume 8 (2010 - 2011): Pages 7 - 10.
- Van Milligan, Tim. “How Composite Propellant Rocket Motors Work - Poster.” Apogee Components ‘Peak of Flight’ 115 (November 21st, 2003): 7.
- Van Milligan, Tim. “Model Rocket Motor Classification System”. Apogee Components ‘Peak of Flight’ 131 (September 20, 2004): 2-5.

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- Aerotech Consumer Aerospace. “Frequently Asked Questions.” Aerotech Consumer Aerospace. June 8th, 2010. (http://www.aerotech-rocketry.com/faq.aspx)
- Coker, John. “Rocket Flight Simulation.” Thrustcurve.org. 1998 - 2010. June 9th, 2010. (http://www.thrustcurve.org/simulation.shtml)
- Mobley, Darrell. “Perfect Fin Fillets.” Rocketry Online. *Info Central*. June 7th, 2010. (http://www.info-central.org/?article=187).
- Van Milligan, Tim. “Get Rid of the Engine Hook.” Apogee Components. March 10th, 2009. June 8th, 2010 (http://www.apogeerockets.com/education/motor_retention.asp)

Websites

- Coker, John. “Thrustcurve.org.” 1998 - 2010. June 9th, 2010. (http://www.thrustcurve.org)

WRITTEN REVIEW QUESTIONS

The cadet is required to review the questions on Composite Propellant, the Heightened Stresses composite propellant place on a model rocket, and Advanced Construction Techniques. The unit AEO can administer the questions. The test can be taken on the Learning Management System (LMS). The minimum passing grade for this review is 70%. Upon successful passage, the cadet must have the AEO sign this document. If LMS is use present results to AEO.

CADET ____

of ____ Squadron, has

successfully passed the review questions on Composite Propellant, the Heightened Stresses composite propellant place on a model rocket, and Advanced Construction Techniques of the Columbia Stage of the Model Rocketry Program.

As the AEO, I have verified the results and found that Cadet ___________________________________ passed with a score that meets or exceeds the minimum requirements of the Columbia Stage of the Model Rocketry achievement program.

____
AEO

COLUMBIA
Official Witness Log

HANDS-ON PHASE

After a cadet completes the review questions, he/she is required to have a Qualified Senior Member (QSM), witness the successful launch and recovery of a rocket, built by the cadet, from a reputable mid/high-power model rocket kit manufacturer. The rocket must fly on a single-use composite propellant motor in the E, F, or G total impulse range. After witnessing the successful flight of this rocket, the QSM must sign this Official Witness Log (OWL).

CADET ____

of ____ Squadron, has

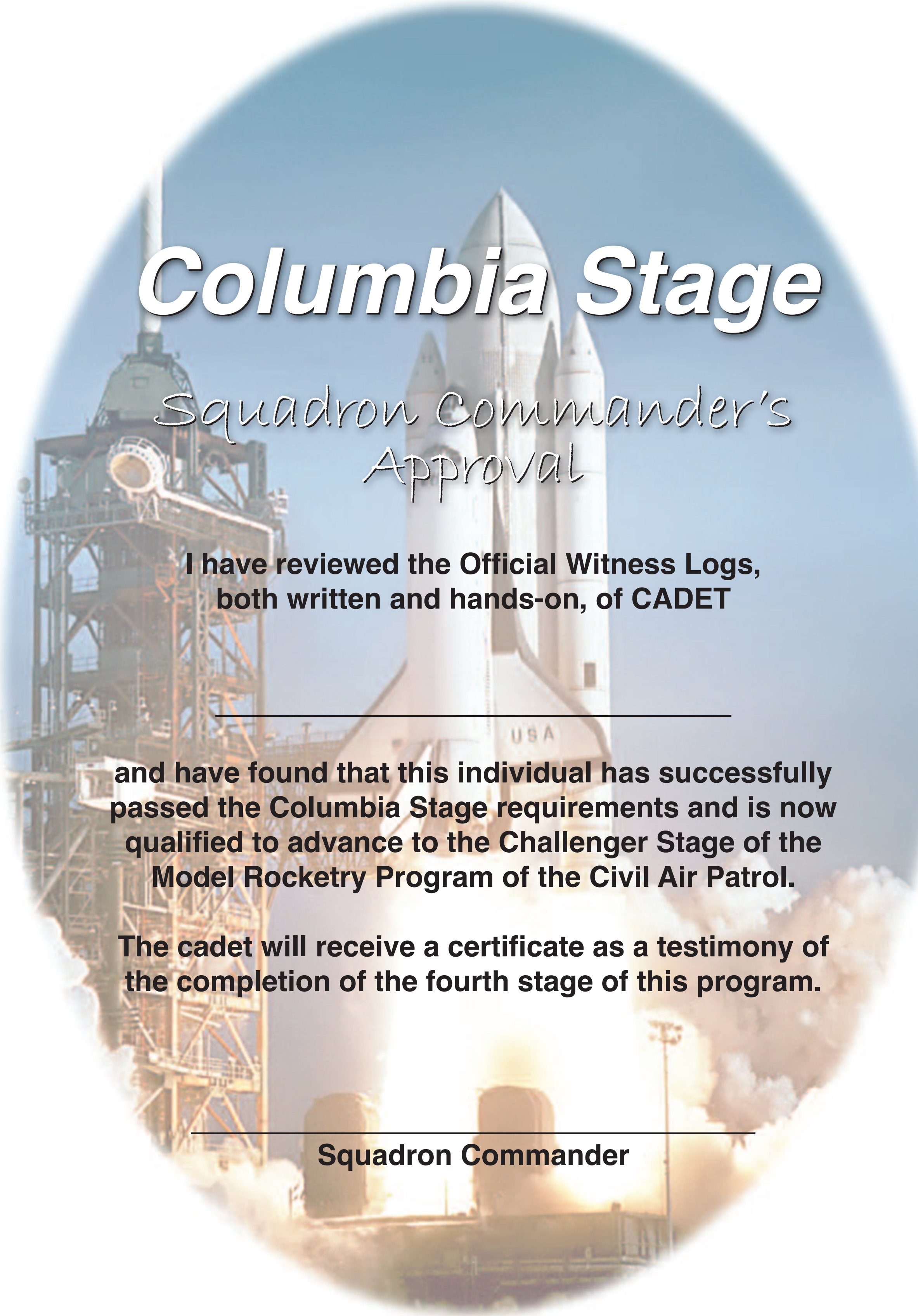
successfully completed the following requirements:

1. Build a mid-power kit from a reputable mid/high-power model rocket kit manufacturer
2. Successfully fly and recover the rocket on either an E, F, or G-class single use composite propellant motor

As a Qualified Senior Member (QSM), I have witnessed the successful flight and recovery of the required rocket, launched on the required motor.

____

QSM



Columbia Stage

Squadron Commander's Approval

I have reviewed the Official Witness Logs, both written and hands-on, of CADET

____

and have found that this individual has successfully passed the Columbia Stage requirements and is now qualified to advance to the Challenger Stage of the Model Rocketry Program of the Civil Air Patrol.

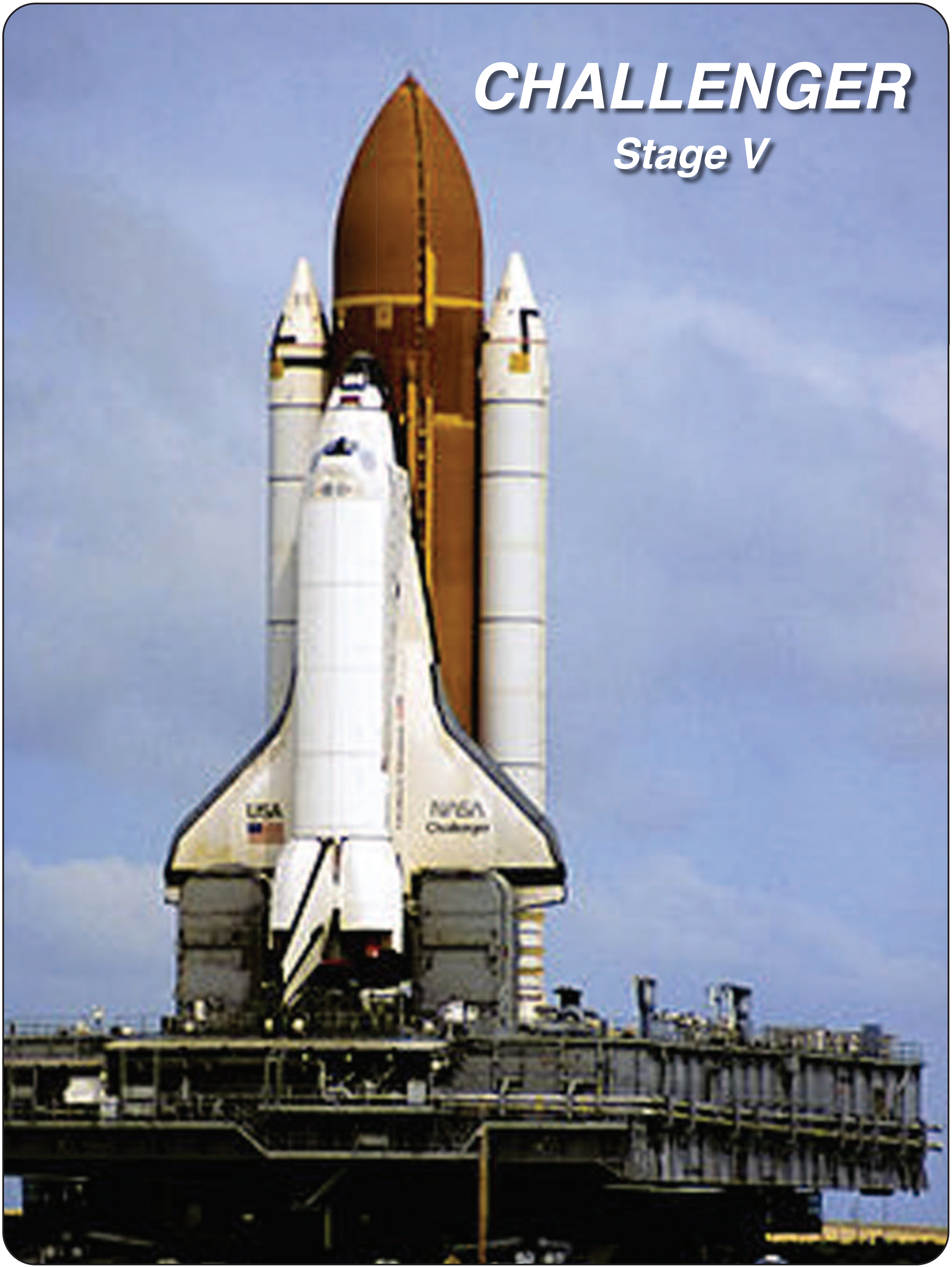
The cadet will receive a certificate as a testimony of the completion of the fourth stage of this program.

____

Squadron Commander

CHALLENGER

Stage V



CHALLENGER
Requirements

CHALLENGER (Stage 5) Requirements:

1. The Written Phase
The cadet must successfully pass a review questions on basic elements of high power rocketry before going to the hands-on phase.

2. The Official Witness Log (OWL) And for review questions
The cadet must have the unit Aerospace Education Officer (AEO) administer the review questions or verify from LMS sign the OWL after the cadet achieves a successful score.

3. The Hands-On Phase
The cadet is required to build a high power rocket. The rocket built in the Columbia (Stage IV) may be suitable for flight as a high power rocket. If so, the same rocket may be used for the Challenger (Stage V) (reference the supplemental information contained in Stage IV as well as possible modifications outlined in Stage V).

4. The Official Witness Log (OWL) For Construction (Optional) And Flight (Required) Of A High Power Rocket
The culmination of CAP's advanced rocketry program will result in the cadet receiving a Junior High Power Rocketry Certification (ages 14 through 17) or a standard (adult) High Power Rocketry Certification (ages 18 and up). Certification is conducted by qualified members of the National Association of Rocketry (NAR), some of who may be members of CAP. The cadet is required to successfully fly and recover the rocket on a high power ("H" or "I") motor. The QSM reviews the NAR documentation certifying the successful flight and then signs the OWL.

5. The Role Of The Squadron Commander
After Completion of the above requirements, the cadet is entitled to receive the Challenger certificate. The squadron commander must review the completed OWL and sign the certificate. Since this represents a major accomplishment in the CAP rocketry program, it is recommended that the certificate be presented at a squadron awards ceremony.

CHALLENGER
Written Phase

MODULE INTRODUCTION

Challenger (Stage V) represents the culmination not just of CAP's advanced rocketry program offered to cadets. Upon successful completion, cadets will be qualified and authorized to fly high power rockets (HPR) in the H and I impulse classifications (up to 640 Newton-seconds total impulse). Cadets between the ages of 14 and 18 will be permitted to fly under qualified adult supervision. Those over age 18 will be permitted to fly HPR on their own, as well as mentor and certify younger cadets.

HPR is an exciting new addition to the basic CAP model rocketry program. For those cadets wishing to pursue it, HPR affords an opportunity to fly rockets much larger, higher, and faster than anything conventional model rocketry has to offer. For those cadets planning to pursue STEM-related curricula in college, they may find that their programs of study will include High Power Rocketry as part of the coursework (a prime example being the United States Air Force Academy). Cadets who have mastered these skills in CAP will be that much farther ahead of their peers when it comes time to work on advanced rocketry projects in college.

Moving into HPR requires some very specific knowledge and skill mastery in order to be successful. In the Columbia stage cadets were introduced to some very important advanced construction techniques which are used throughout HPR. The Challenger stage will provide an introduction to the rules and regulations that govern HPR, as well as the advanced propulsion systems which are utilized.

OVERVIEW OF HIGH POWER ROCKETRY

High power rocketry is defined and/or regulated by three distinct entities: the national rocketry organizations; specifically, National Association of Rocketry (NAR) and Tripoli Rocketry Association (TRA), the National Fire Protection Association (NFPA), and the Federal Aviation Administration (FAA). NAR and TRA are involved with establishing certification procedures, safety codes, and motor classifications. HFPA has established instructional guidelines and specific standards for the design, construction, reliability, and power limitations of the manufacturing of motors, as well as other aspects of HPR so as to minimize hazards associated with the activity. The FAA, as one can imagine, is concerned with the potential hazard presented to aircraft, and regulates HPR under Federal Aviation Regulation (FAR) Part 101, Subpart C.

In the early 1980s, interest began growing in flying rockets of significantly higher power than what was typical for model rockets (the upper limit commonly being the D motor, although there were some manufacturers producing E and F motors). The introduction of composite propellant is basically what allowed for the development of HPR.

Initially, NAR wanted to focus on model rocketry and not involve itself in HPR. With a need for a national organization to govern HPR, the Tripoli Rocketry Association was formed. In the years following the establishment of TRA, NAR realized the value of HPR and subsequently adopted its own program. Today, TRA is exclusively an HPR organization, while NAR is involved in model rocketry as well as HPR. The two organizations have a very cordial relationship where, under most circumstances, a member of TRA can fly at a NAR event and vice versa. TRA does have a "research" category which NAR does not have; consequently, NAR members would have some limitations imposed at TRA launches that are classified as "research".

Additionally, TRA does not have a Junior HPR certification category, as NAR does. Therefore, CAP cadets wishing to pursue Stage V will be required to join NAR in order to complete the program. The current cost for a cadet's one-year membership in NAR is $25.

MOTOR IMPULSE CLASSIFICATIONS

By now, cadets who have progressed this far in the rocketry program are familiar the motor classifications that were established by NAR in the early days of model rocketry. HPR uses that same basic formula to classify motors; it just goes much farther down into the alphabet! The following chart will show model-rocket-classified motors on the left side (also classified as low and mid power motors), and HPR motors shown on the right side. To review: Ns means Newton-second, which represents one Newton of force for one second.

Class	Impulse Range (Ns)
A	1.25+ to 2.5
B	2.5+ to 5.0
C	5.0+ to 10.0
D	10.0+ to 20.0
E	20.0+ to 40.0
F	40.0+ to 80.0
G	80.0+ to 160.0

Class	Impulse Range (Ns)
H	160+ to 320
I	320+ to 640
J	640+ to 1280
K	1280+ to 2560
L	2560+ to 5120
M	5120+ to 10240
N	10240+ to 20480
O	20480+ to 40960

The chart stops at "O" because that is currently the largest commercially manufactured HPR motor. The term "low power" generally applies to motors rated D and below, and "mid power" applies to motors rated E through G.

RELOADABLE MOTORS

The purpose of using reloadable rocket motors in high power rocketry is based solely on economics. While the up-front costs are higher (due to the initial acquisition of reusable motor hardware), after only a few uses, reloadable motors become more economical than motors that are used once and then thrown away. For this reason, high impulse rocket motors are almost exclusively offered as reloadable—there are very few high-impulse single use motors available.

Of the reloadable motors that are available commercially, some are *almost completely* reusable (including the nozzle), while others are *mostly* reusable (where the nozzle is replaced after each flight). There are also some types where all of the reloadable parts are assembled at the factory, and others where none of the parts are assembled and that job is left to the user (again the issue is economics). It follows then, that a design that requires users to essentially assemble the motor from a bag of parts would be less expensive than the same type of motor that was offered by a manufacturer who had to pay a worker to perform the assembly in a factory.

A visual comparison of two of the most common types of reload "kits" is shown to the right:

Aerotech brand reloads require assembly

The aluminum casing that houses the propellant and motor components is reusable and has virtually an indefinite life. Reusability is the key to the economy of using reloadable motors over single-use. To illustrate, a squadron could purchase a casing for all cadets to use. The shared use of the hardware would greatly reduce the cost of each individual flight.

Cesaroni Pro29 and Pro38 brand reloads come completely assembled—components shown to the left are installed in the black liner at the factory.

HIGH POWER ROCKETRY CERTIFICATION

A through G motors are available at many hobby stores and may be purchased without any certification. The purchase of H motors and above does require a certification affidavit (cert card) that indicates the individual is qualified to fly (and therefore purchase) such motors. Certification is broken down into three levels:

Level 1: H and I motors
Level 2: J through L motors
Level 3: M motors and above

The NAR Jr. HPR certification is a modification of Level 1. CAP cadets who certify under this category, will be permitted to fly H and I motors *under qualified adult supervision*. A qualified adult supervisor is defined as a NAR adult member with HPR certification of Level 1 or above. The adult member of NAR does *not* need to be a member of CAP; however, any AEO (or any adult member of CAP for that matter) may join NAR and become HPR certified—in doing so, he or she would provide an in-house resource that would be a valuable asset to any cadet advanced rocketry program.

High power certified fliers are limited to the total impulse they may fly on a single flight. For example, a Level 1 flier could not fly a motor cluster, or fly a multi-stage rocket, using two I motors because that would put the total installed impulse into the J impulse classification. Consequently, a J impulse flight would require a Level 2 certification.

Certification for Jr. Level 1 is simple and straightforward. The candidate must first build a rocket capable of accomplishing a successful flight powered by an H or I motor. He or she must then demonstrate a successful flight using an H or I motor in the presence of a designated individual or certification team. In order for the certification to be valid, the candidate must be a member of NAR. Membership may be activated at the time of the certification flight. In other words, the NAR membership application may be submitted at the same time the HPR certification flight is accomplished.

CAP cadets 18 and over may choose to go beyond HPR Level 1. Advancement to the higher levels requires a thorough understanding of, and experience in, high power rocketry. For example, certification for Level 2 is somewhat more complex than Level 1. The candidate must build a rocket capable of accomplishing a successful flight powered by a J, K or L motor. It is permissible to use the same rocket for the Level 2 flight as was used for the Level 1 flight (assuming the rocket can withstand the stresses of a significantly more powerful motor). The candidate must also pass a written exam consisting of 50 multiple-choice questions relating to the technical and safety aspects of high power rocketry. Once the test is passed and a successful flight is accomplished on a J, K, or L motor, the individual is certified at Level 2. The same type of witness and membership requirements for Level 1 also apply for Level 2.

Certification for Level 3 requires the candidate to submit a project proposal to a NAR member specifically designated to approve such projects. The rocket design must meet specific minimum objectives in the areas of construction, stability, recovery, and electronics. Once the design is approved and construction is completed, the flight must be powered by a commercially manufactured and certified motor, the minimum impulse of which, exceeds 5,120 Ns, but is not greater than 40,960 (M through O motors). Authority to witness and act as a certifying official is limited to a specific group of individuals so designated by NAR.

Certification levels must be accomplished in sequence and no levels may be skipped. Once cadets turn 18, they may certify either through NAR or TRA. It is only the Jr. HPR certification that must go through NAR (since NAR is the only one of the two organizations that offers that certification category).

USE OF ON-BOARD ELECTRONICS

On-board electronics can be used extensively in high power rocketry—or not at all. The only "electrical" requirement is that the motor be ignited by electrical means, which is accomplished with a ground controller that is not part of the rocket. A high power rocket can operate in flight much like a simple Estes-type model rocket, wherein the motor propellant burns through thrust termination, a "delay" element burns which produces no thrust and allows the rocket to coast to apogee, and then a small black powder ejection charge (activated by the burn-through of the delay charge) fires to deploy the recovery system—all of which required no on-board electronics. The following paragraphs will, however, discuss some of the many electronic devices available for use in HPR.

Barometric Altimeter

Consider the following scenario:

> An on-board electronic device could allow the recovery system deployment of a rocket to happen in stages, rather than a single event. At apogee, a small drogue parachute could be released in order to disturb the aerodynamic characteristics of the rocket. This would allow the rocket to descend rapidly but prevent it from turning into an aerodynamic projectile. Once the rocket descended to a few hundred feet above the ground, the device could then release the main parachute and allow the rocket to gently land.

The described device is now in widespread use in high power rocketry in many forms and variations, and offered by many manufacturers (and represents perhaps the most common usage of electronic devices in high power rocketry). An added bonus to flying this type of device is that it will report the altitude recorded at apogee.

Timer

Another useful device is an event timer. The device utilizes an accelerometer which will detect motor ignition as well as burnout. The timer normally has the capability to trigger at the moment it detects a particular event, or to enter a time delay mode before it triggers. Zero delay would be useful in igniting a secondary cluster of motors on the ground. Time delays are useful in initiating a staging sequence, jettisoning a set of strap-on motors, or air starting a secondary cluster on a single stage rocket.

Flight Computer

Flight computers are very powerful devices which can be programmed to perform a variety of functions. One such computer has the capability to detect five different events and react instantly or after a preprogrammed elapsed time. A flight events recorder will provide a readout either real-time (for telemetering to the ground) or stored for later down-load of parameters such as acceleration, ascent velocity, altitude (both barometric and accelerometer), and descent rate. Interface with a PC will create line graphs of the events vs. time. Many flight computers have the capability of storing recorded data from multiple flights, thus reducing the need to carry a computer to the flying field.

Telemetry

As mentioned above, the capability exists to telemeter the on-board data real-time to a ground receiver. The telemetry stream could also include a real-time video image from an on-board camera.

Locating Devices

Depending on the flying field, the rocket may land in an area obstructed with trees or tall grass which can hamper recovery. The terrain may contain dips or ravines which could also disrupt the direct line-of-sight of a landed rocket. There are devices available which can aid the recovery process which range from the very simple and inexpensive, to quite sophisticated (and expensive).

The simplest and least expensive is the audible locator. The device activates during a recovery event (either drogue or main deployment) and emits a high decibel sound which serves to give away its location. The down-side to this device is that once on the ground, the audio radius is greatly reduced. It is certainly better than nothing and its effectiveness has been proven on numerous occasions.

An intermediate level of sophistication (and cost) is a radio beacon. A transmitter rides on board the rocket and emits a pulsed signal. The signal is picked up by a directional receiver and the variations in intensity of the signal will lead the receiver in the direction of the transmitter.

The most sophisticated (and expensive) is GPS. However, the receiver will give the locating team a graphic map (to include lat/long) of precisely where the rocket is located. What could be easier?

Imagery

Still and full motion video imagery is easily obtainable with tiny on-board mounted cameras. The imagery can be recorded internally for later download, or, as stated earlier, it can be telemetered to the ground real-time during flight.

FAA REQUIREMENTS

It doesn't take a rocket scientist to figure out that a high power rocket zooming up to several thousand feet at several hundred miles an hour would pose a hazard and even a danger to aircraft. Hence, the FAA is very concerned about HPR activities. So much so that there is an entire regulation devoted to the subject: FAR 101, Subpart C (as mentioned previously). Local chapters of the national organizations (known as "sections" for NAR, and "prefectures" for TRA) will have accomplished all the prerequisites and coordination required to conduct an HPR event by the time the rocket fliers show up on launch day. That is one of the many advantages of flying with a local club—all the regulatory issues have been taken care of for you!

The FAA has a very concise description of what it considers a model rocket and what it considers an HPR. That description (taken directly from FAR Part 101, Subpart C) is reprinted here in its entirety:

101.22 Definitions.

The following definitions apply to this subpart:

(a) *Class 1—Model Rocket* means an amateur rocket that:
- (1) Uses no more than 125 grams (4.4 ounces) of propellant;
- (2) Uses a slow-burning propellant;
- (3) Is made of paper, wood, or breakable plastic;
- (4) Contains no substantial metal parts; and
- (5) Weighs no more than 1,500 grams (53 ounces), including the propellant.

(b) *Class 2—High-Power Rocket* means an amateur rocket other than a model rocket that is propelled by a motor or motors having a combined total impulse of 40,960 Newton-seconds (9,208 pound-seconds) or less.

(c) *Class 3—Advanced High-Power Rocket* means an amateur rocket other than a model rocket or high-power rocket.

BUILDING A HIGH POWER ROCKET

The building techniques outlined in Stage IV are to be utilized as well in Stage V. Stage IV described an option by which the same rocket built for Stage IV could also be used for Stage V. If that option was exercised, then no further construction is necessary (although some modification may be required). If the Stage IV rocket is not configured for HPR flight (and can not be modified), then the cadet will need to construct another rocket. It may be in kit form or may be of his or her own design. There are numerous kit manufacturers as well as vendors that sell individual rocket parts. There are also several design software programs available (some for purchase, some for free). A resource list will be provided at the end of the chapter.

An example of a rocket kit that is suitable for both Stages IV and V.
Shown are the piece parts of the LOC/Precision "Graduator"

The assembled Graduator rocket stands 40 in. tall and
can fly on E through H motors—a very versatile rocket.

Due to the much higher altitudes and higher speeds capable of HPRs, a method of venting internal pressure must be included in the rocket design. As a rocket rises rapidly, external air pressure will become lower due to the rise in altitude. Air trapped inside the body tube will therefore become greater than the outside pressure, and the possibility of the nose cone popping off becomes real. With the nose cone deployed, the rocket will become unstable, the parachute could come out, and a complete vehicle break-up could occur all while the rocket is still under power. A small vent hole (approx. 1/8 in. diameter) positioned anywhere near the rear of the nose cone's internal position in the body tube, and forward of the top motor mount centering ring should prevent a failure due to internal pressure build-up. The method described should be suitable for most rockets constructed in Stage V. Note however, that rockets with larger internal volumes will require multiple and/or larger vent holes. An Internet search using the terms "rocket vent hole formula" will return helpful information. Any rocket built in Stage IV that is planned to be flown for Stage V should be modified as described above (if not already accomplished).

Effective motor retention is also important for HPR flights. While a good snug friction fit is feasible, it is strongly recommended that a more positive method of motor retention be employed for a Stage V rocket. The arrangement illustrated in the Stage IV text is one such method. Others are available. An Internet search using the terms “hpr motor retention” will return helpful information.

Due to the higher altitudes attainable on HPR flights, the possibility of loosing the rocket increases. Size and terrain of the flying field will also be a factor in successfully locating a rocket after it’s landed. If there is any concern regarding the possibility of loosing sight of the rocket, then some method of electronic locating assistance should be considered. The small, inexpensive, audible locating devices mentioned in the “Onboard Electronics Section” would be an excellent way of helping assure rocket recovery. Additionally, the size of the parachute may be lessened, either by cutting a spill hole in the top or by constraining the shroud lines. Using interchangeable parachutes could also be utilized—a larger one for lower altitude flights and a smaller one for higher altitude flights. Keep in mind that a smaller parachute will increase the decent rate and increase the chance of landing damage. A broken fin, for example would disqualify a candidate on a certification flight.

FLYING A HIGH POWER ROCKET AND LAUNCH SAFETY CONSIDERATIONS

Preparation for flight will follow the same basic procedure used for Stage IV. Note that different rocket designs will require different preparation procedures. For example, a “piston” parachute deployment system does not require the use of protective wadding, so the preflight preparation for that type of rocket would differ somewhat from a more conventional design. Rockets built from kits will have “preflight instructions” included with them. Rocket motor manufacturers will include instructions for motor assembly, preflight preparations, and post flight handling.

The easiest way to accomplish the flight is to seek out a local NAR section. NAR has a section directory on its website. The local NAR section should also be able to provide a qualified team or individual who can perform the Jr. HPR certification. If a section is not established in the local area, also consider TRA. Tripoli prefectures will often have NAR members who are qualified to conduct certifications. If neither of these options is viable, contact CAP National Headquarters for guidance.

Rocket motors are often available for purchase from venders that will be set up on the flying field on the day of the launch. If the local rocket club does not have on-site vender support, motors may also be purchased through mail order.

The important elements of launch safety are covered in the high power rocketry safety codes of TRA and NAR. The on-line NAR code is included here in its entirety.

Effective August 2012

1. **Certification.** I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.

2. **Materials.** I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.

3. **Motors.** I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.

4. **Ignition System.** I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the “off” position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.

5. **Misfires.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher’s safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

6. **Launch Safety.** I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.

7. **Launcher.** I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor’s exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.

8. **Size.** My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.

9. **Flight Safety.** I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.

10. **Launch Site.** I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).

11. **Launcher Location.** My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.

12. **Recovery System.** I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

13. **Recovery Safety.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

MINIMUM DISTANCE TABLE

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 -- 320.00	H or smaller	50	100	200
320.01 -- 640.00	I	50	100	200
640.01 -- 1,280.00	J	50	100	200
1,280.01 -- 2,560.00	K	75	200	300
2,560.01 -- 5,120.00	L	100	300	500
5,120.01 -- 10,240.00	M	125	500	1000
10,240.01 -- 20,480.00	N	125	1000	1500
20,480.01 -- 40,960.00	O	125	1500	2000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors.

REFERENCE MATERIAL

Design Software Resource List

For Purchase:

RockSim
http://www.apogeerockets.com/Rocksim/Rocksim_information

For Free:

OpenRocket
http://openrocket.sourceforge.net/

RASAero
http://www.rasaero.com/

NAR Jr. HPR Certification Instructions

http://www.nar.org/hpcert/jrhppreq.html

Note: Additional information, references, and links regarding the advanced rocketry program may be found in the "General Information" section of Stage IV.

SUMMARY

High Power Rocketry is an exciting new component to the cadet program. Cadets age 14 and over may explore new areas of advanced rocketry concepts that go far beyond the basic model rocketry program. The advanced rocketry program has a very practical application to those cadets wishing to pursue STEM programs of study in college.

CAP units that become active in advanced rocketry and are fortunate enough to be located near an active HPR club will find that rocketry launches may become a much anticipated monthly activity. Monthly club launches often attract dozens (sometimes upwards of a hundred or more) participants flying a wide variety of rocket designs. In addition to cadets flying their own rockets, they will be able to see many advanced rocket designs, some of which resemble actual full size NASA sounding rockets! Additionally, active rocket clubs typically have numerous experienced and seasoned rocket fliers, many of whom would be more than happy to help cadets (and adults) get started in this dynamic activity.

Example of an advanced 2-stage HPR designed to fly on combinations of
J, K, L, M, or N class motors (with booster requiring at least an L motor for stable flight).

CHALLENGER
Official Witness Log

WRITTEN REVIEW QUESTIONS

The cadet is required to review questions on High Power Rocketry (HPR). The unit AEO can administer the questions. The questions can be taken on the Learning Management System (LMS). The minimum passing grade is 70%. Upon successful passage, the cadet must have the AEO sign this document. If LMS is used present results to AEO.

CADET ____

of ____ Squadron, has

successfully passed the review questions on Composite Propellant, the Heightened Stresses composite propellant place on a model rocket, and Advanced Construction Techniques of the Columbia Stage of the Model Rocketry Program.

As the AEO, I have administered the questions or verified results and found that Cadet

____________________________ passed with a score that meets or exceeds

the minimum requirements of the Columbia Stage of the Model Rocketry achievement program.

____
AEO

CHALLENGER
Official Witness Log

HANDS-ON PHASE

After a cadet completes the review questions, he/she is required to fly the rocket and have a Qualified Senior Member (QSM), validate the documentation of the successful launch and recovery of a rocket, built by the cadet. The rocket must fly on a composite propellant motor in the H or I total impulse range. After witnessing the successful flight of this rocket, the QSM or must sign this Official Witness Log (OWL)*.

CADET ____

of ____ Squadron, has

successfully completed the following requirements:

Constructed a High Power Rocket (HPR) either from a kit or by his/her own design or utilize the rocket kit built from Stage IV (if suitable).

Accomplish a NAR Jr. Level 1 HPR certification or Level 1 HPR certification (as appropriate for cadet's age) and validated by a NAR certification team or authorized individual.

As a Qualified Senior Member (QSM), I have evaluated the required NAR documentation and certify that the cadet meets the requirements of Stage V hands-on phase.

____

QSM

*While the QSM will not (in most cases) be the NAR certifying authority, it is still recommended that the QSM observe the flight.

Challenger Stage

Squadron Commander's Approval

I have reviewed the Official Witness Logs, both written and hands-on, of CADET

____

and have found that this individual has successfully passed the Challenger Stage requirements and has now completed the Advanced Rocketry Program of the Civil Air Patrol.

The cadet will receive a certificate as a testimony of completion.

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Squadron Commander

NOTES

Civil Air Patrol
www.capmembers.com/ae

Air Force Association
www.afa.org

AIR FORCE
STEM

Partners in Aerospace and STEM Education